Teaching in the operating room: trends in surgical skills transfer in ophthalmology

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Abstract: Cataract surgery is arguably the most commonly performed operation in ophthalmology. Surgical skills transfer from experienced surgeons to resident surgeons is complicated by the fact that the teaching surgeon primarily acts as an observer rather than directly performing the procedure. Therefore, wet lab and simulator training are utilized to reduce the learning curve of the novice surgeons, which establishes tissue awareness, dexterity and muscle memory required to perform each step of the procedure, safely. Access to a wet lab and simulator environment is accomplished by establishing a surgical training curriculum in residency programs. In the operating room, topical anesthesia is a safe alternative for teaching cataract surgery. There are three well-described approaches to teaching individual steps of cataract surgery: forward, "backwards", and deconstructed step-by-step instruction. Simulator training can be incorporated prior to live patient experience or integrated concurrently with learner presence in the operating room. The trend towards a competency-based instruction model has necessitated appropriate evaluation tools that include Objective Assessment of Skills in Intraocular Surgery (OASIS), Global Rating Assessment of Skills in Intraocular Surgery (GRASIS), and the International Council of Ophthalmology's Ophthalmology Surgical Competency Assessment Rubrics (ICO-OSCAR). We review the literature on trends in surgical teaching in ophthalmology, with the focus on cataract surgery instruction to the novice surgeon.

Keywords: Cataract surgery; surgical instruction; ophthalmology education

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Introduction

The transfer of surgical skills from one generation of surgeons to the next, generally using the apprenticeship model, has long been a cornerstone of resident education. Cataract surgery is arguably the most commonly performed procedure for a general ophthalmologist, and therefore the most important surgical skill to acquire in an ophthalmology residency (1). However, there are several important factors that make teaching and learning cataract surgery challenging for both the attending and surgeon-in-training. Performance of successful intraocular surgery demands fine manual dexterity, an in-depth knowledge of ocular anatomy, and a thorough understanding of surgical principles such as phacodynamics. There are no inconsequential steps in good phacoemulsification, and each step of the procedure relies on the successful completion of the steps preceding it. While the resident surgeon is operating, the attending surgeon is primarily an observer, with limited ability to intervene and prevent potentially visually devastating complications. In addition, patient expectations for a good surgical outcome are very high.

In recent years, there has been an effort to standardize how surgical skills are acquired and evaluated in graduate medical education. In the United States, the Accreditation Council for Graduate Medical Education (ACGME) has

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implemented several programs designed to shift the medical education paradigm to a competency-based model. This started with the six General Competencies introduced in 1999, followed by the Outcome Project in 2001 (2,3). The ACGME identified six areas of core competency to be taught and evaluated by residency programs, including patient care, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, professionalism, and systems-based practice. The American Board of Ophthalmology has included its own surgical competency requirement for residents (4). The Outcome Project expanded on those goals and directed training programs to include specific learning objectives related to the core competencies, to evaluate residents using more objective tools, and to use the data generated from those assessments to facilitate individual and program performance improvements (5). Most recently, all specialties have been entered into the Next Accreditation System (NAS). This system utilizes milestone reporting, which paves the way for using a competency-based model to assess resident performance and determine progression through a training program, rather than a process or time-based model (6,7). These changes have prompted the implementation of a standardized program of surgical teaching within most ophthalmology programs (8). In this paper, we will review current trends in cataract surgery education, and ways to optimize the learning process for surgeons-in-training.

Establishing a surgical curriculum

In 2004, Carter and Lee offered a comprehensive plan to incorporate the requirements of the ACGME mandate into an ophthalmology training program, including an assessment of surgical competency (9). They proposed matching specific tools (such as written and oral examinations, global evaluations and direct observation) to specific core competencies, to create a matrix for meeting the mandate requirements. This was followed by another seminal paper from the University of Iowa, which described the results of the 4-year effort to implement those changes, and the barriers to their implementation (5). They expanded on the earlier paper and created ten tools to assess the progress of their residents, with respect to achieving the mandated competencies. These included the residency curriculum, direct observation of a live patient encounter, a journal club, a 360-degree evaluation (combining input from all members of the patient care team), a modified Dreyfus scale faculty global evaluation, the Iowa Cataract Surgical and Laser Curriculum, written and oral examinations, self-reflection exercises, grand rounds presentations, and a learner portfolio.

According to a recent survey of program directors in the US by Lotfipour *et al.*, the majority of residents perform their first phacoemulsification as a primary surgeon during their second year of ophthalmology training, although the mean number of cases performed in the second year was only 25 (8). Sixty-five percent of these program directors reported that achieving mastery of the appropriate training milestone was the primary factor in determining when a resident will begin phacoemulsification as the primary surgeon, and approximately 56 percent felt that inadequate resident knowledge and surgical skill base were barriers to starting phacoemulsification earlier in the residency. Binenbaum and Volpe's survey of program directors in 2006 revealed that up to 10 percent of residents had difficulty learning to perform cataract surgery, and that frequently those difficulties went undetected until the third year of ophthalmology training, when the majority of surgeries were performed (10). Importantly, this struggle frequently correlated with difficulty transitioning into a 'thriving surgical ophthalmologist' after residency (10). A structured surgical curriculum helps to identify these struggling residents earlier, prompting additional study outside the operating room and facilitating the on-time progression to performing phacoemulsification as the primary surgeon.

The learning curve of cataract surgery has been described in several papers, including a 2007 work by Randleman *et al.* that found that complication rates and phacoemulsification time significantly decreased after 80 cases. A comparative case series from Taravella *et al.* in 2011 similarly found that surgical competence was generally achieved after performing 75 cases (11,12). The most difficult steps to learn were wound integrity (ensuring a water-tight wound), nucleus disassembly and removal, cortex removal, and capsulorrhexis (12). Previous studies have suggested that the rate of complications during phacoemulsification is higher for novices than for experienced surgeons (13-16), although visual outcomes after 30 days appear to be similar for residents and attending surgeons (17,18). In 2009, Rogers *et al.* performed a retrospective review evaluating the impact of their structured Iowa Cataract Surgical Curriculum on cataract surgery complication rates among third-year residents (19). The competency-based surgical curriculum included a structured wet lab and simulator program during the first year, use of the "backing-in" technique to allow first-year residents to complete some portions of senior

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resident cases, formative feedback immediately after cases, and capsulorrhexis practice during the second year. They found that after the surgical curriculum implementation, rates of posterior capsular tear or vitreous loss decreased from 7.17% to 3.77% (P=0.001), confirming the importance of a standardized approach to surgical instruction.

Training in a simulated environment

Use of a simulated surgical environment to practice the steps of phacoemulsification allows residents to achieve basic proficiency in a low-stress environment, promoting surgical confidence and patient safety (20). Currently, roughly 98% of US-based training programs offer access to a wet laboratory, with more than half providing access to a virtual reality simulator (8,10). Evidence continues to support that a simulated training environment improves resident performance in the operating room. There are three cataract surgery simulators on the market today: The MicroVisTouch (ImmersiveTouch, Chicago, IL, USA), PhacoVision (Melerit Medical, Linkoping, Sweden) and the Eyesi (VRMagic Holding AG, Mannheim, Germany). The Eyesi is the only simulator with validated construct validity, demonstrated by Mahr and Hodge with the anterior segment anti-tremor and forceps training modules (21). Solverson *et al.* subsequently reported that Eyesi simulator use resulted in improved dexterity for beginner surgeons (22). McCannel *et al.* reported that utilizing the Capsulorrhexis Intensive Training Curriculum (CITC) on the Eyesi reduced the rate of errant capsulorrhexis for resident surgeons in the operating room (23). Inexperienced surgeons who have trained on the simulator demonstrate shorter phacoemulsification times with fewer intraoperative complications, and the benefit of such training appears to extend to novice surgeons who have performed 75 or fewer cases (24,25).

Several important resources exist that can be utilized to establish a more traditional simulated surgical wet laboratory training experience. A "how-to" manual for setting up a surgical wet laboratory was provided in a 2009 paper by Henderson and colleagues (26). They emphasized six important factors including setting up the physical space, establishing appropriate faculty and curriculum, obtaining the practice eye, stabilizing the eye, preparing the eye, and funding the laboratory. The Iowa group presented their Iowa Ophthalmology Wet Laboratory Curriculum, which includes specific learning objectives, as well as a pretest and a posttest that assesses the effectiveness of each intervention (27). The curriculum utilizes the Schön reflection model (designed to improve learner understanding and motivation for learning) and offers a detailed scoring rubric based on the Dreyfus model of expertise (27). A recent randomized controlled trial from Mishra *et al.* suggests that augmenting wet laboratory experience with instructional videos may further improve resident performance (28).

Approach to intraoperative instruction

Understanding your learner

It is imperative for the attending surgeon to understand the level of expertise of each learner. Surgical instruction for novices should focus on maximizing patient safety, developing basic proficiency and learning surgical fundamentals. With intermediate surgeons, emphasis should be on improving efficiency, learning more advanced surgical techniques, and developing an approach of how to manage complications. Expert management of complications and approaches to complex cases such as dislocated intraocular lenses should be reserved for advanced surgeons. Authors cannot always agree on the definition of a novice, intermediate and advanced learners. As noted previously, Randleman *et al.* report a significant reduction in sentinel complications following the first 80 resident cases, with an incidence of complications of 5.1% up to 80 cases, and 1.9% after 80 cases have been completed (11). Others report a significant reduction in posterior capsular rupture from 10.8% to 1.7% after the first 30 cases are completed (29). After 160 cases, posterior capsular tears and vitreous loss incidence tends to plateau but improvement in phacoemulsification efficiency continues beyond 200 cases (11). Based on the literature, we propose that learners between 1–80 cases are treated as novice surgeons, those between 80–200 cases are intermediate learners, and >200 cases are advanced learners. We will further focus our review on the teaching approach for the novice surgeon.

Choice of anesthesia

The majority of small incision phacoemulsification surgery is performed under topical anesthesia with light sedation. One may presume that retrobulbar anesthesia would provide a safer operating environment for residents, with better ocular stability and cooperation from the patient, although data shows otherwise. Unal *et al.* performed a

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direct comparison of phacoemulsification of topical and retrobulbar anesthesia, and there was no difference between the two groups in complication rates (30). The supervising surgeon may still choose to utilize retrobulbar anesthesia based on patient characteristics such as cognition, systemic conditions or other clinical scenarios, like nystagmus. However, these cases should not be used as teaching cases for the novice surgeon. One can conclude that topical anesthesia, paired with appropriate patient selection, is a safe choice for novice surgeons.

Sequence of surgical instruction

Three main approaches have been discussed pertaining to the sequence of teaching phacoemulsification technique: (I) a stepwise "forward" approach, where each step of the surgery is taught in order of its progression; (II) a "backwards" or "reverse" approach, where the steps at the end of the procedure are taught first; (III) a "deconstructed" approach, where the procedure is divided into multiple parts and each part is individually taught (18,31-33).

The classic forward approach utilizes the step-by-step progression in teaching phacoemulsification, starting with creating a clear corneal incision and ending with the lens insertion, viscoelastic removal, and wound closure. The "backwards" or "reverse" approach presumes a lower incidence of complications during the final steps of the procedure (as compared to the initial steps), and therefore advocates for starting the resident with lens insertion and viscoelastic aspiration first, followed by quadrant removal, lens nucleus disassembly, and finally wound creation and capsulorrhexis. The backwards approach was first proposed by Fischer *et al.* from Brazil (34). This approach has been strongly supported by experienced cataract instructors who found it safer and more effective (31,32). Until recently, there had been no direct comparison between the two approaches. Suryawanshi *et al.* performed a direct comparison of the forward method and the "reverse" method in the rate of posterior capsular rupture in the novice surgeon (up to 30 cases) (35). There was no statistically significant difference between the two approaches in the rate of posterior capsular rupture, which was 6.2% by forward approach and 4.6% using the "reverse" approach. The authors concluded that either method, under supervision, is appropriate to use when teaching novice surgeons.

Kloek *et al.* (2014) describe a "deliberate" approach to phacoemulsification surgical teaching (33). They deconstruct the procedure into seven surgical steps and introduce a curriculum that initially focuses on each step of the procedure individually. They ranked the difficulty of each step from least to most difficult in the following order: lens insertion, wound construction, hydrodissection, aspiration of cortex, nucleus disassembly, quadrant removal of lens, and, finally, capsulorrhexis. Residents were to perform only one of the seven steps during each surgery. The group showed that this deconstructed approach to teaching phacoemulsification improved junior resident preparedness for highly concentrated surgical rotations in their senior year. Similarly, Rogers *et al.* in Iowa utilize a mixed deconstructed and "backwards" approach in their renowned surgical curriculum (18). Analysis of outcomes pre-surgical curriculum and post-surgical curriculum shows reduction in sentinel complication rate.

Approach to managing complications

The rate of senior surgeon intervention and completion of the case is 4-8%, depending on the level of the trainee (36). Some advocate using a "stop and swap" approach, where the lead surgeon intervenes temporarily to assist with managing the complication. The resident surgeon then proceeds with the remainder of the case (37). Theoretically, this may help build confidence in the beginner surgeon.

Integrating the simulator and the operating room

We discussed above the strong body of evidence for incorporating a simulated environment in surgical education in ophthalmology. Surgical programs have tried various methods of incorporating simulators into surgical education. Some advocate for performing a complete case without mastering each portion of the procedure individually, or mastering each segment of the surgery prior to completing a full case. Thomsen and colleagues suggest a 6-step approach to mastery of cataract surgery (25). They propose starting with theoretical education and wet-lab training, followed by simulator training prior to operating room exposure. After performing phacoemulsification on 25 patients, they complete additional simulator training before returning to the operating room. In this model, the novice surgeon would perform complete cases on the surgical simulator, before doing so on live patients (25). Others have suggested using the simulator for high repetition and motor memory for each individual step of phacoemulsification first. In this model, the learner would, for example, practice nucleus disassembly technique on the simulator multiple

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times, and then practice the same skill in the OR, with the attending surgeon completing the rest of the case (33). Both methods appear to be plausible and have not been directly compared in the literature.

Methods of assessment post-operatively

In response to the implementation of competency-based milestones in surgical education by regulatory bodies, several objective evaluation tools have been developed. These include the Objective Assessment of Skills in Intraocular Surgery (OASIS), the Global Rating Assessment of Skills in Intraocular Surgery (GRASIS), and the International Council of Ophthalmology's Ophthalmology Surgical Competency Assessment Rubrics (ICO-OSCAR) (38-40).

OASIS is an evaluation tool developed to minimize subjective input. This tool is a one-page assessment (or a computer-based form) for data collection that evaluates pre-operative planning, intraoperative choices and details, and post-operative assessment for up to 1 year of follow-up (38). Cremers also developed the GRASIS. It was designed to be complementary to OASIS by incorporating subjective feedback, and evaluates such skills as microscope use, instrument handling, flow of operation, and surgical professionalism, among others (39). Tools exist for assessment of individual techniques as well. Smith *et al.* developed a validated assessment for performance of capsulorrhexis, hydrodissection and phacoemulsification portions of cataract surgery, using the framework of GRASIS (41,42).

ICO-OSCARs are a rubric-based assessment which has a broad library of additional surgical rubrics beyond the rubrics for cataract surgery. In an OSCAR, the procedures are broken down into steps with each step then being graded according to the scale of novice, beginner, advanced beginner, and finally competent. Each step and accompanying grade has a description of the necessary performance needed to achieve that level on the scale. The tools are designed to allow feedback and assessment directly at the conclusion of a surgical case for immediate feedback to the learner (40).

New developments in surgical education

Virtual simulation is the future of surgical education. Although simulators were initially used to teach the basics of phacoemulsification surgery, they have since found other uses. The Eyesi simulator has a vitreoretinal training module for practicing vitrectomy and epiretinal membrane peels. Interestingly, there appears to be no transfer of skills between performing cataract surgery in the simulation environment and vitreoretinal procedural performance (43). A simulation environment is now available for retrobulbar blocks using an Ophthalmic Anesthesia Simulation System (OASiS) (44). Development of customized 3D printing has created training opportunities by creating orbital models and models of intraocular tumors for training and surgical planning (45,46). The field of ophthalmology continues to expand its horizons using technology developed for use in other fields to benefit our patients.

Conclusions

Strategies for optimizing surgical education will continue to develop as residency programs shift to the competency-based paradigm, and will likely need to evolve alongside technological advances. The current body of literature suggests that residents can safely learn cataract surgery using a number of different instructional techniques and curricula, but an organized, systematic approach to surgical education will offer the greatest ability to identify and utilize evidence-based best practices. More investigation is needed to understand how to best tailor the instructional approach to the learner, to maximize patient safety and effective skills transfer. These advancements in surgical education will be beneficial to patients, new cataract surgery trainees, and experienced surgeons acquiring new skills as the field evolves.

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